AFOSR-TR-97

0526

REPORT DOCUMENTATION PAGE

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE Sept. 1997

3. REPORT TYPE AND DATES COVERED Final Report

4. TITLE AND SUBTITLE Creep Resistance of Gamma TiAl Microstructures

5. FUNDING NUMBERS AFOSR Grant F49620-94-1-0380

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8. PERFORMING ORGANIZATION REPORT NUMBER

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110 Duncan Avenue, Suite B115
Bolling AFB, DC 20332

nA

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

19971021 175

11. SUPPLEMENTARY NOTES
Attn: Dr. Spencer Wu

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Unlimited

DISTRIBUTION STATEMENT E
Approved for public release
Distribution Unlimited

12b. DISTRIBUTION CODE

13.
The development of microstructure and its influence on creep properties has been studied in two Ti-48Al-2Cr-2Nb alloys. The addition of 0.9 atomic % Mo to the Ti-48Al-2Cr-2Nb composition results in the formation of the ordered B2 phase. The presence of this phase along with a small amount of α_2 at grain boundaries was found to effectively limit grain growth at 1125°C during heat treatments that produce equiaxed γ microstructures. The $\gamma \rightarrow \alpha$ transformation produces α_2 plates with several orientation variants within γ grains during subsequent annealing of the equiaxed γ microstructures below the α-transus. Formation of this α_2 morphology results from rapid up-quenching and this structure persists through annealing, cooling, and creep testing. Differences in minimum creep rates for several microstructures containing varying amounts multi or single variant γ/α_2 grains are shown to be minimal. The presence of Mo has also resulted in improved creep resistance in equiaxed γ, and $\gamma + \alpha_2$ + B2 structures as compared to similar microstructures in the Ti-48Al-2Cr-2Nb alloy. Deformation during creep at 760°C at stresses between 200 and 400 MPa occurs by a combination of twinning and dislocation glide without recrystallization, resulting in power-law stress exponents in the range of 6 to 9. Only minimal strain path dependence of the minimum creep rate was detected in a comparison of creep rates in stress jump, stress drop, and single stress tests.

14. SUBJECT TERMS Gamma Titanium Aluminides, Creep Deformation

15. NUMBER OF PAGES 4

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	

0 8 SEP 1997

Creep Resistance of γ - TiAl Microstructures

Final Technical Report
AASERT Grant F49620-94-1-0380
1 July 1996 - 30 June 1997

Submitted to:

Air Force Office of Scientific Research

110 Duncan Avenue, Suite B115

Bolling AFB, DC 20332-0001

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Creep Resistance of Gamma TiAl Microstructures

1.0 Research Progress

Research activities during the third year of the gamma-TiAl creep resistance project have focused on creep testing and evaluation of creep deformed structures. Some additional studies on the development of microstructural features as a function of heat treatment conditions have been performed. Some of the project results were presented at the 1997 TMS spring meeting and are being submitted to Metallurgical Transactions for publication.

The development of microstructural features, particularly the formation of multivariant alpha2 plates in gamma grains has been studied in detail in the previous year due to its relevance to hot-worked structures. It has been determined that the formation of alpha2 plates with several variants within gamma grains is a direct result of the gamma -> alpha transformation on heating. During rapid heating of an initially equiaxed structure to temperatures within the gamma + alpha phase field, alpha plates rather than alpha grains preferentially form. Cooling then results in a structure which contains multivariant alpha2 plates in gamma grains. Slow heating favors the formation of alpha grains rather than plates. These results, along with those of the prior two years, indicate that initial structure, heating rate, annealing temperature, and cooling rate all substantially influence resulting microstructure. This is particularly important since variations in these parameters often occur as a function of position during processing of commercial components.

Additional creep testing at 760°C has been performed at lower stress levels and for other microstructures in the Ti-48Al-2Cr-2Nb and Ti-48Al-2Cr-2Nb-1Mo for comparison to the data already acquired in the first two years of this project. In a variety of microstructural conditions, which include equiaxed gamma, duplex, and multivariant alpha2 structures, both alloys exhibit at least two regions of secondary creep rate stress exponent dependence. At high stresses exponents are near 8 while at lower stress they are near 4. Tests performed in the higher stress exponent regime have shown that the secondary creep rate surprisingly do not vary significantly with changes in alpha2 phase morphology over a range of structures, including a low lamellar fraction duplex structure and structures with varying proportions of lamellar grains and multivariant alpha2 plates within gamma grains. Tests during the second year have also indicated that no significant prior deformation history effects exist in these structures. Additional testing has shown that the multivariant alpha2 microstructures are stable during aging at the creep testing temperature and result in secondary creep rates comparable to those in prior tests with no prior aging. In general, the alloy containing molybdenum has lower creep rates for the equiaxed and multivariant type microstructures.

Experiments have also shown that gamma grain size affects minimum creep rates in equiaxed structures at grain sizes in the range of 45 to 100 microns. Grain size dependence has been reported in the literature for some binary aluminum rich alloys, but no detailed work had been performed on titanium rich alloys and the origins of the grain size dependence are not yet understood. Further investigation of aging in equiaxed structures of both alloys investigated has shown that some minor changes in alpha2 and B2 fraction occur with aging at 760°C and that the resulting secondary creep rate increases by 10 to 50 times with aging for times on the order of 1000 to 2500 hours.

Analysis of creep deformed structures has shown that a combination of dislocation and twin activity exists at 760°C for stresses between 50 and 400 MPa. Cross twinning has been noted and some twins have been seen propagating across alpha2 plates in the multivariant structures. In general the fine scale deformation structure varies significantly from grain to grain implying a strong orientation dependence of deformation and/or a significant contribution of accommodation related deformation.

Completion of work on this project with funding outside the AFOSR AASERT program is planned for the upcoming year. Further examination of the aging response in equiaxed structures and tests to determine the presence and amount of grain boundary sliding that may be occurring in these structures will be performed. Continued analysis of the mechanisms of fine scale creep deformation response in these materials is also planned.

2.0 AASERT Student

Eric A. Ott, the graduate student working on this project, has completed his Ph.D. Thesis Overview as of mid-June and is expected to complete his Dissertation by 12-98. As in previous years, close contact with external thesis committee members, Dr. Patrick Martin of Rockwell International and Dr. James Williams of General Electric Aircraft Engines, has continued.